



Gas Fermentation & Modular Manufacturing

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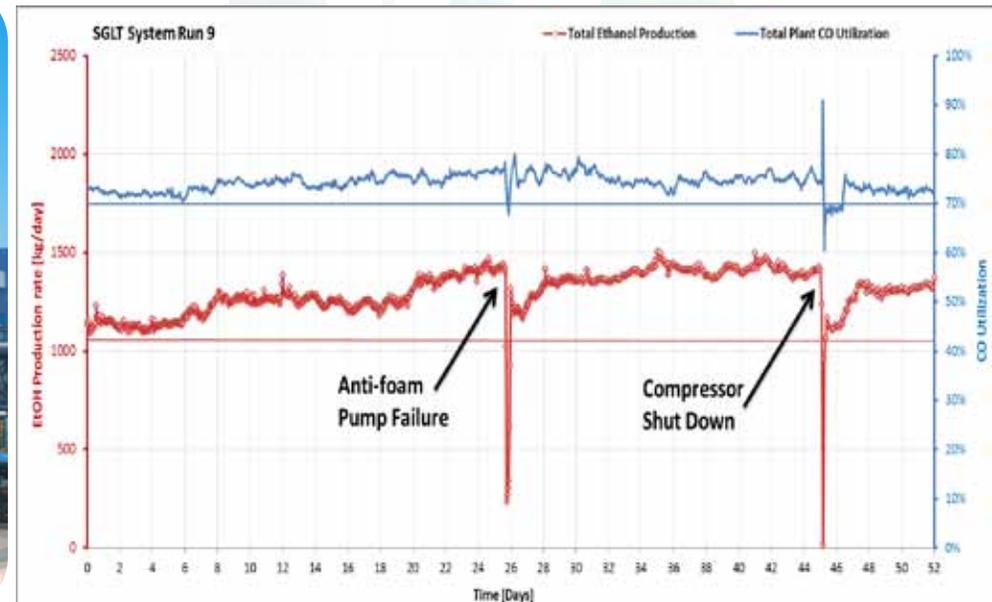
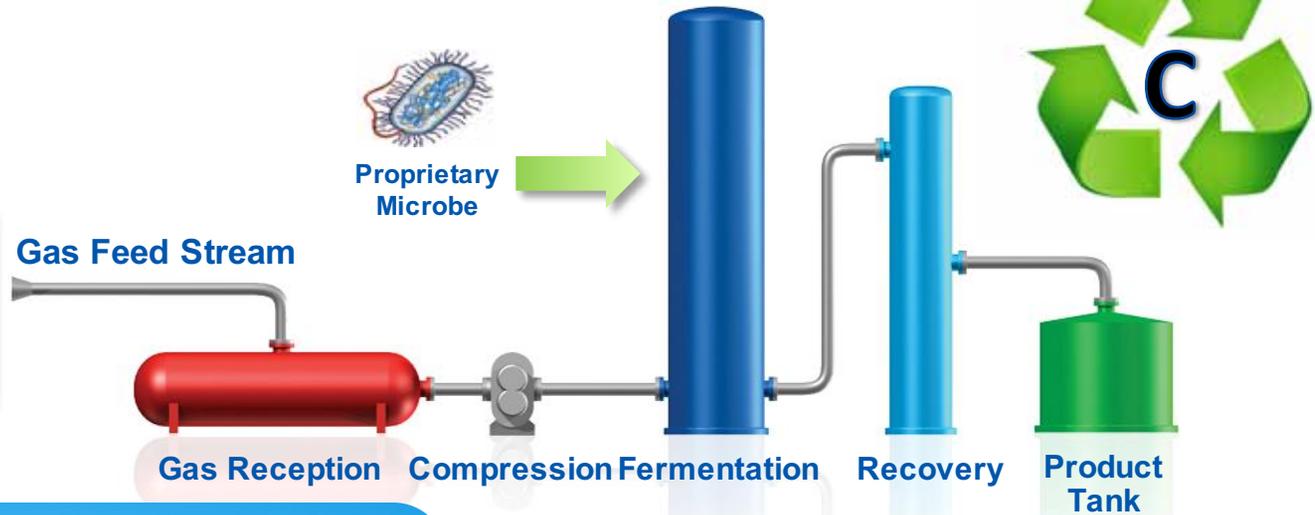
December 4, 2015

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The LanzaTech Process

Gas fermentation technology converts C-rich gases to fuels and chemicals



Performance milestones achieved and exceeded for >1000 hours



Most Recycled Material on Earth: STEEL

88% recycling rate

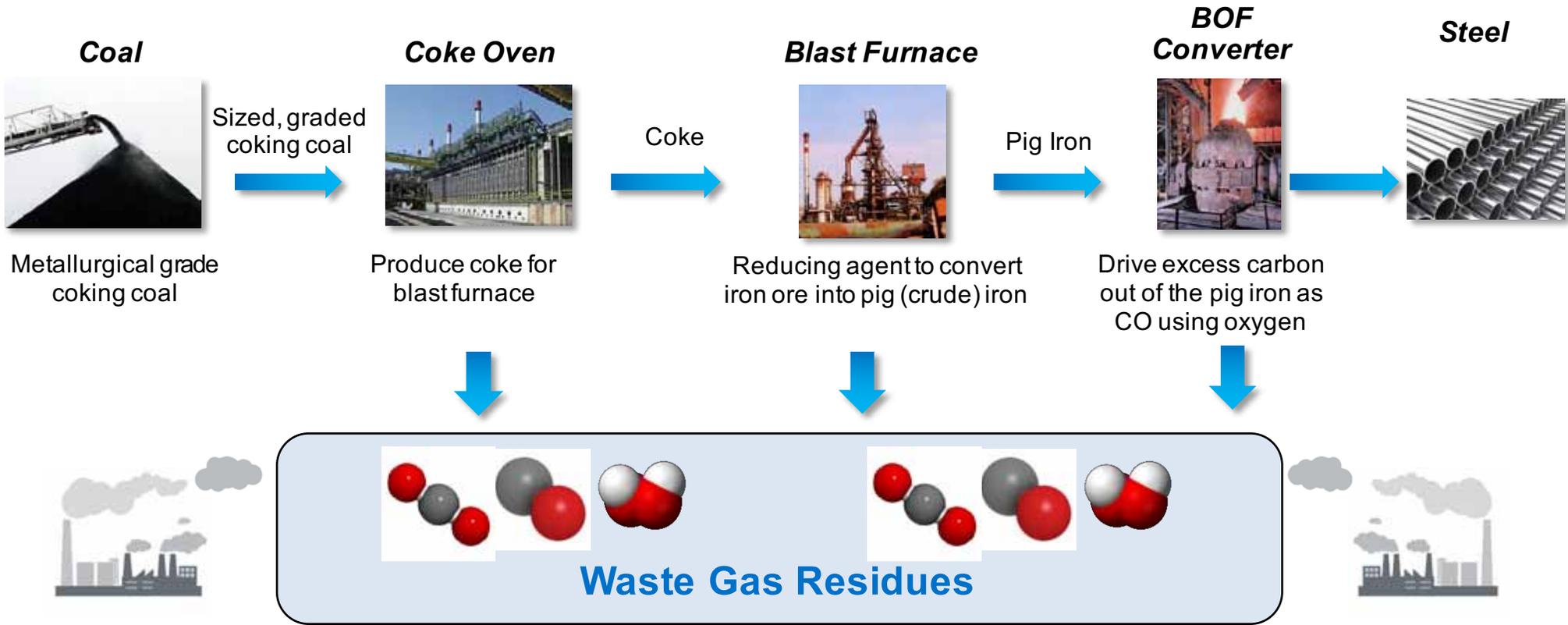


2 out of 3 tons of new steel=old steel



Steel Making 101

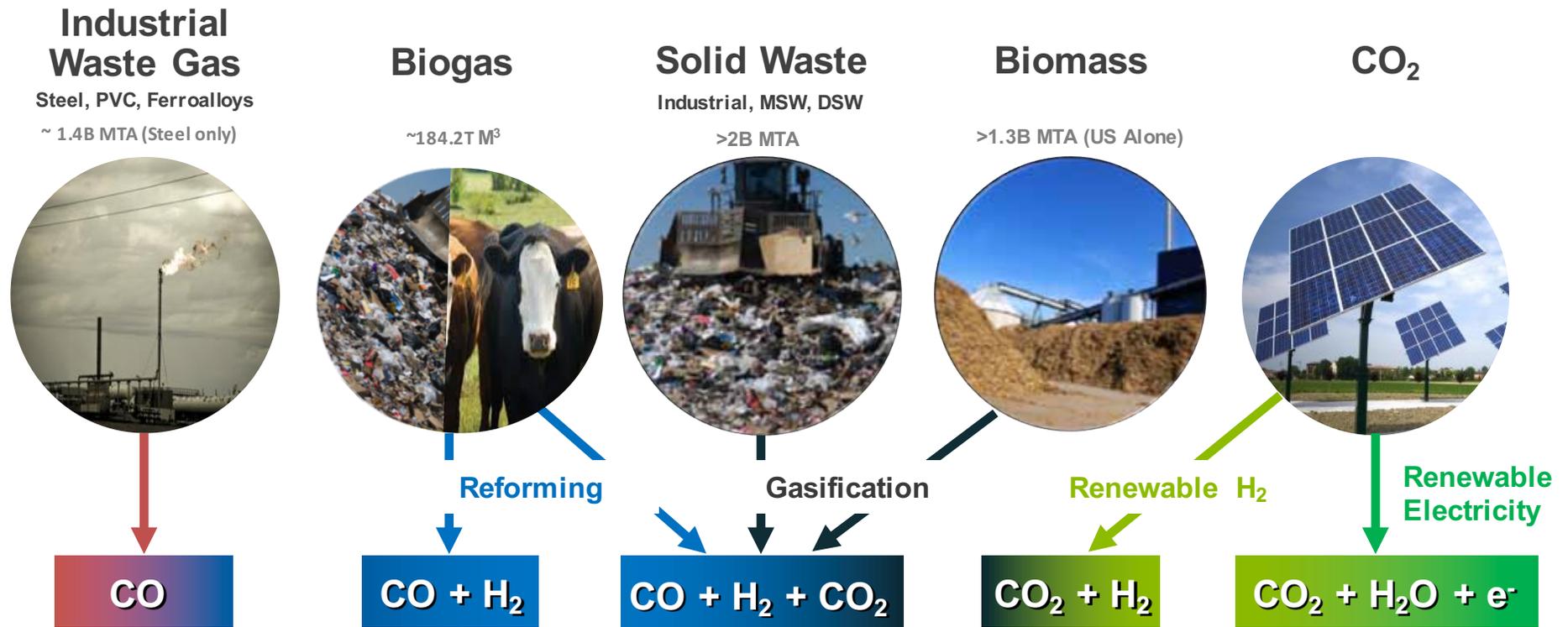
Carbon is needed in steel-making



These gases are a byproduct of the CHEMISTRY of steel making



Waste Carbon Streams as a Resource



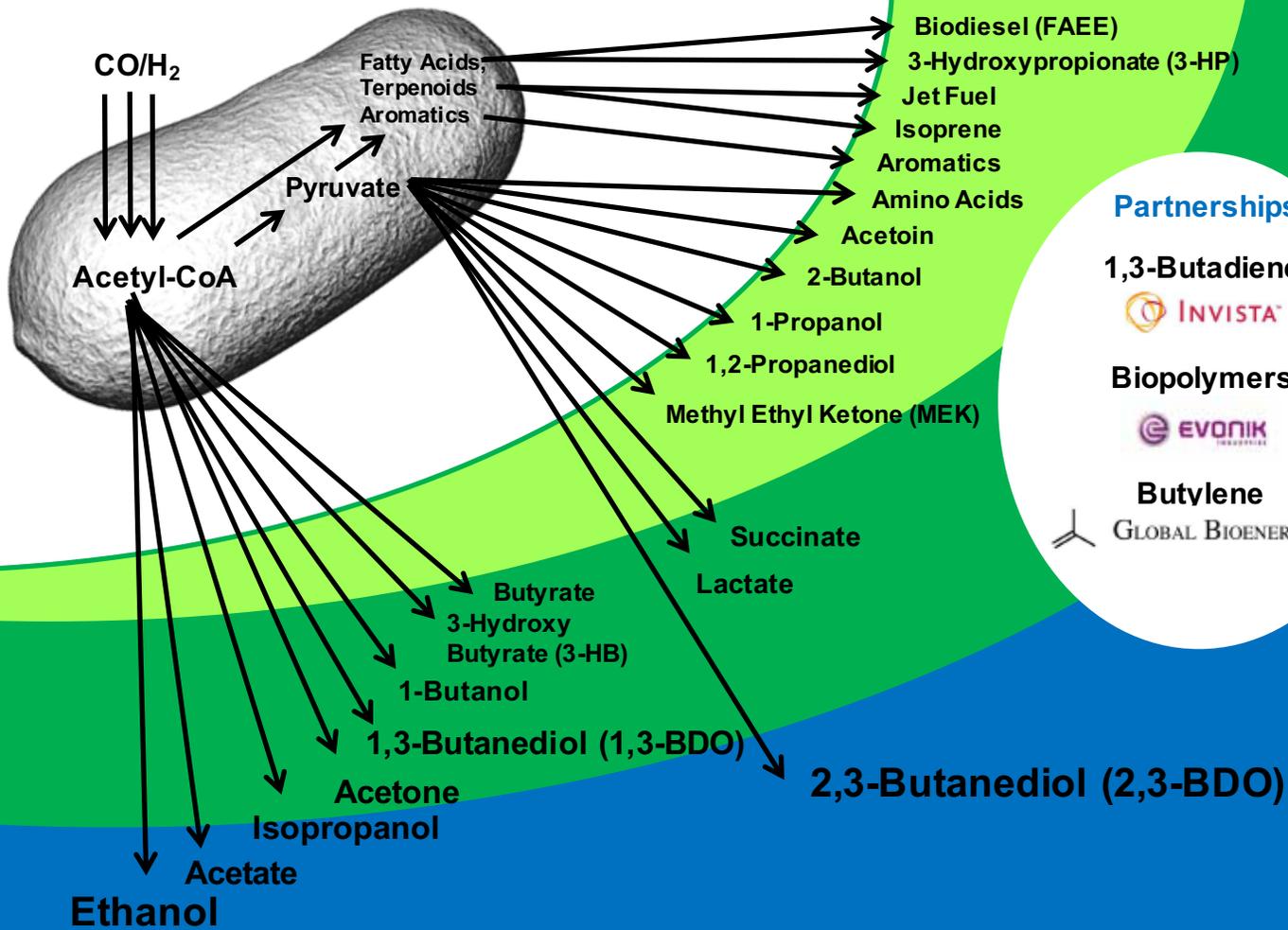
Gas Fermentation

- ✓ Available
- ✓ High Volume/Low Intrinsic Value
- ✓ Most Point Sourced
- ✓ Non-Food

Source:
2010 global production; 2012 proven gas reserves data (IEA, UNEP, IndexMundi, US DOE Billion Ton Update)



1 Organism, over 25 Products...



Discovery

Lab Scale Process

Scaled-Up Process

Partnerships

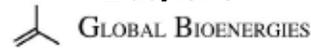
1,3-Butadiene



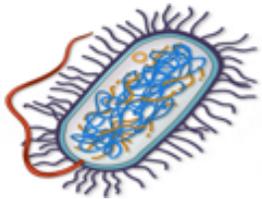
Biopolymers



Butylene



Scaling Up LanzaTech's Technology



Commercial Scale-up Factor Less Than What Has Been Proven at Demo Scale



Global Technology “Lab”

Data, Data, Data

40,000 combined hours on stream

Multiple runs exceeding 2000 hours



Multiple Demo plants at various scales all demonstrating different key aspects of process



Pre commercial steel mill demonstrations

- ✓ Performance milestones exceeded
- ✓ First commercial in design; fully financed in China



*Mitigating Scale up Risk through
Successful Technology
Demonstration*

*Exceeded design capacity
Local chemicals, water*



ArcelorMittal Gent



Electricity generation

€300M investment in electricity from CO in Gent

Fully integrated Flagship mill

ArcelorMittal supports a carbon smart future

Carbon recycling with LanzaTech

First of a kind project in EU Q2 2017

Aggressive deployment across EU post Gent

Power from renewables not carbon



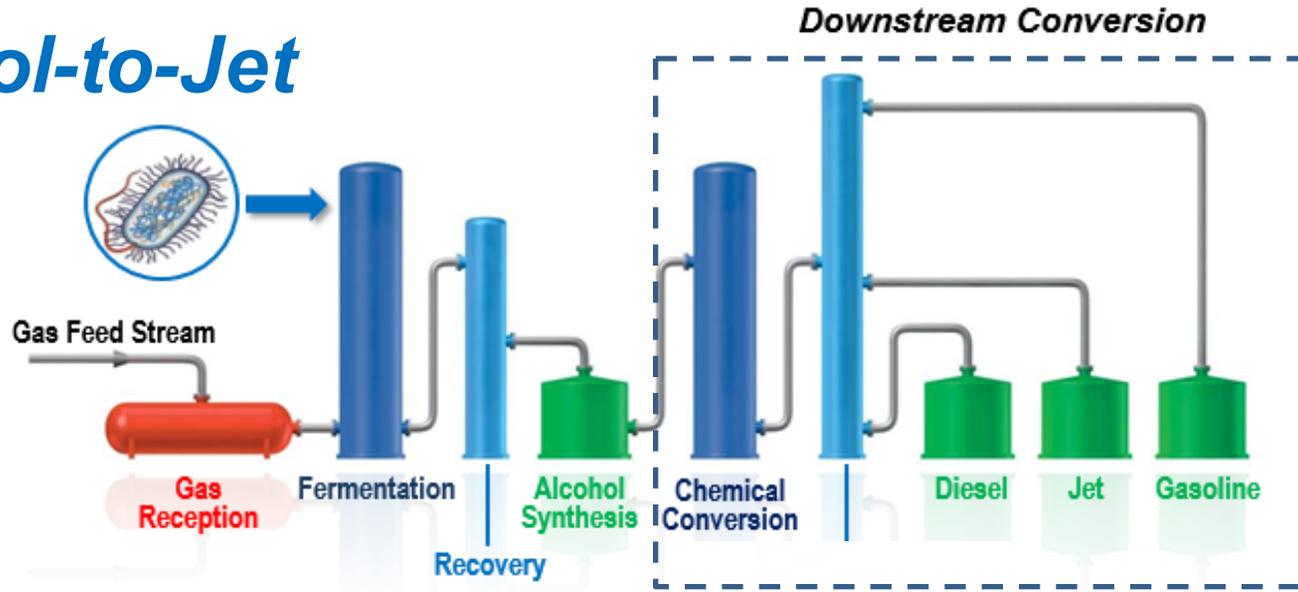
- 120,000 tons/annum CO₂ reduction
- 300,000 tons/annum CO₂ captured for future reuse
- 60k MTA ethanol capacity
- Adding value to CO



Downstream Conversion: Hydrocarbon Fuels Process

Alcohol-to-Jet

Key Enabler:
Price and Availability of Alcohol



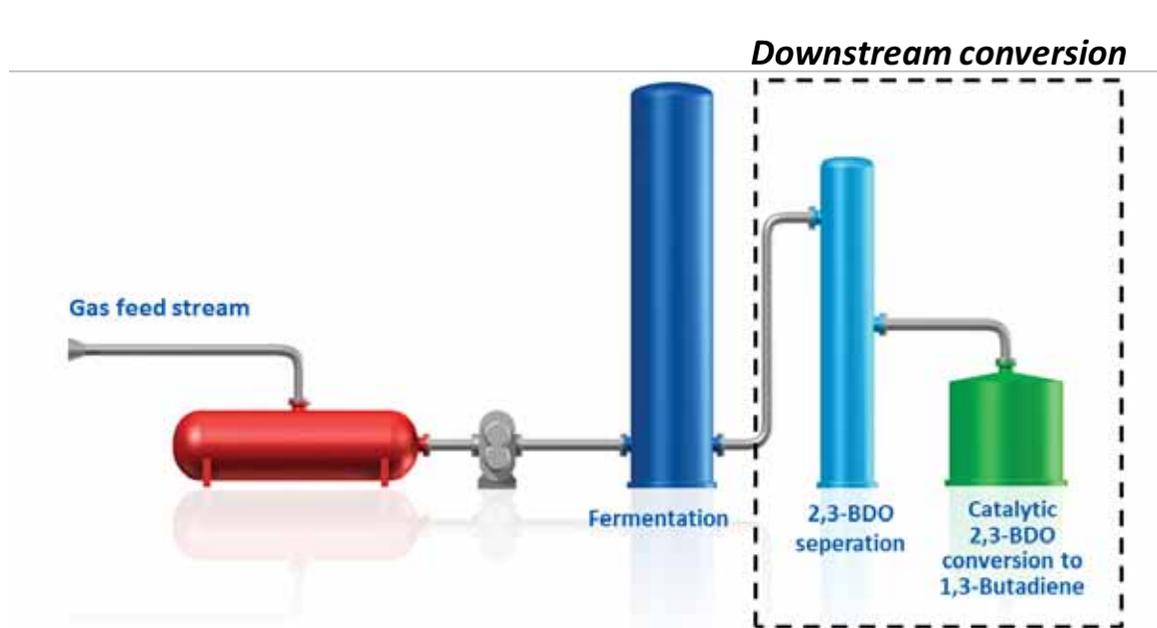
ASTM Certification In Progress



Flight Demo in 2016



Downstream Conversion: 2,3-BDO to Butadiene



LanzaTech 

SK 

INVISTA™ 

Pacific Northwest NATIONAL LABORATORY 

Butadiene Product Markets



Styrene Butadiene Rubber (SBR)
US \$13 billion/yr



Polybutadiene Rubber (BR)
US \$8 billion/yr



Acrylonitrile Butadiene Styrene (ABS)
US \$16 billion/yr



Nylon 6,6
(from Adiponitrile/HDMA)
US \$7 billion/yr

Köpke and Havill, *Catalyst Review* 27: 7-12 (2014)
Köpke et al., *Appl Environ Microbiol* 80: 3394-403 (2014)
Köpke et al., *Appl Environ Microbiol* 77: 5467-75 (2011)



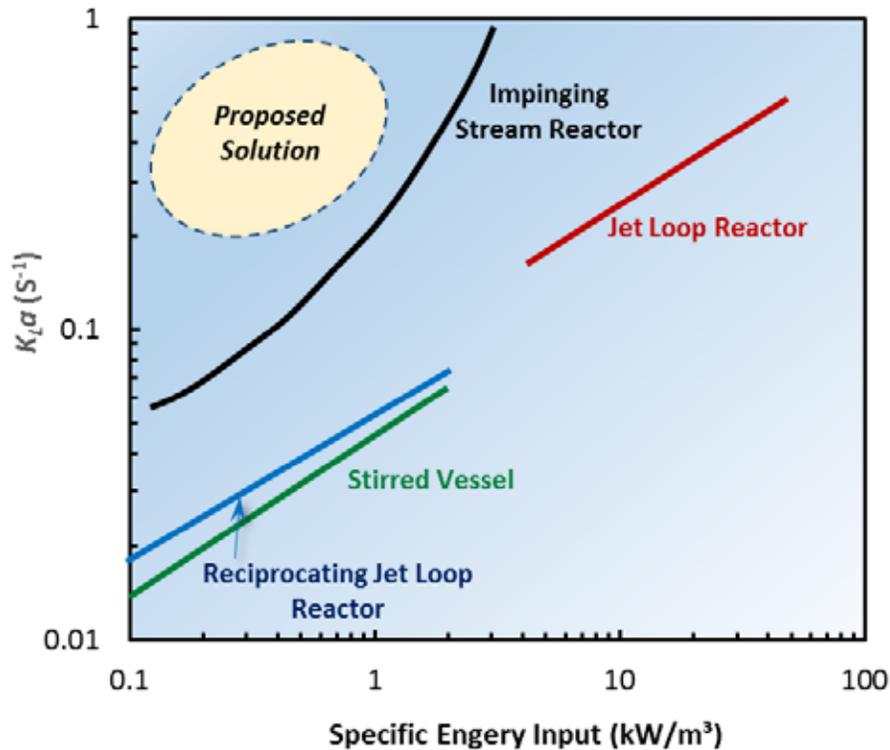
LanzaTech 
capturing carbon. fueling growth.

Example: Modular Manufacturing for Capturing Flared/Vented Natural Gas

- **Associated natural gas is the most abundant and readily available point source of methane in the US**
 - Flared natural gas increased in the US from 119 BCF in 2005 to 213 BCF in 2012
 - Bakken flaring grew from a modest 3,260 MMcf in 2005 to 79,564 by 2012 growing its share of US flared natural gas from 3% to 37% by 2012
- **Bakken alone could support 100's of small GTL plants to capture wasted natural gas**
- **Modular manufacturing is required for small-scale deployment to reduce the overall capital and footprint.**
- **Modular manufacturing requires process intensification of existing GTL technologies including gas fermentation**

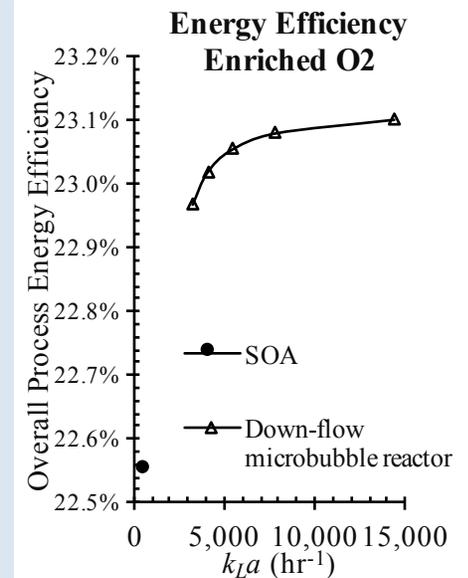
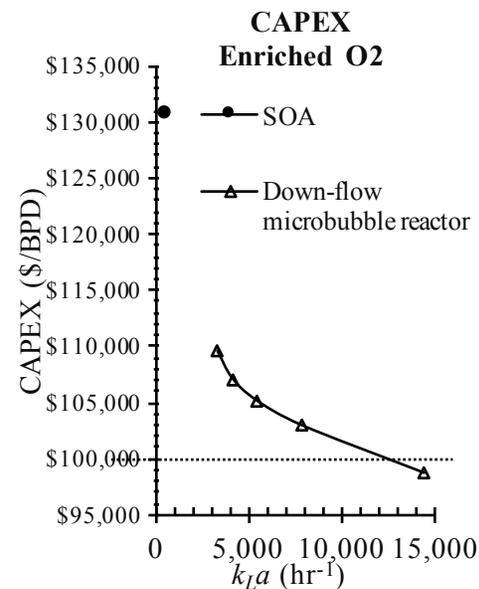


Process Intensification through Improved Mass Transfer



- To achieve high mass transfer rates generally requires an increase in energy input
- Proposed solution represents a novel, proprietary bioreactor concept that can achieve high mass transfer rates at reduced energy inputs

- ▶ Proposed bioreactor concept offers reductions in capital and operating costs of the *bioreactor system* over state of the art (SOA) up to:
 - 60% CAPEX savings
 - 35% reduction in energy usage



Bioreactor Development for Natural Gas Fermentation

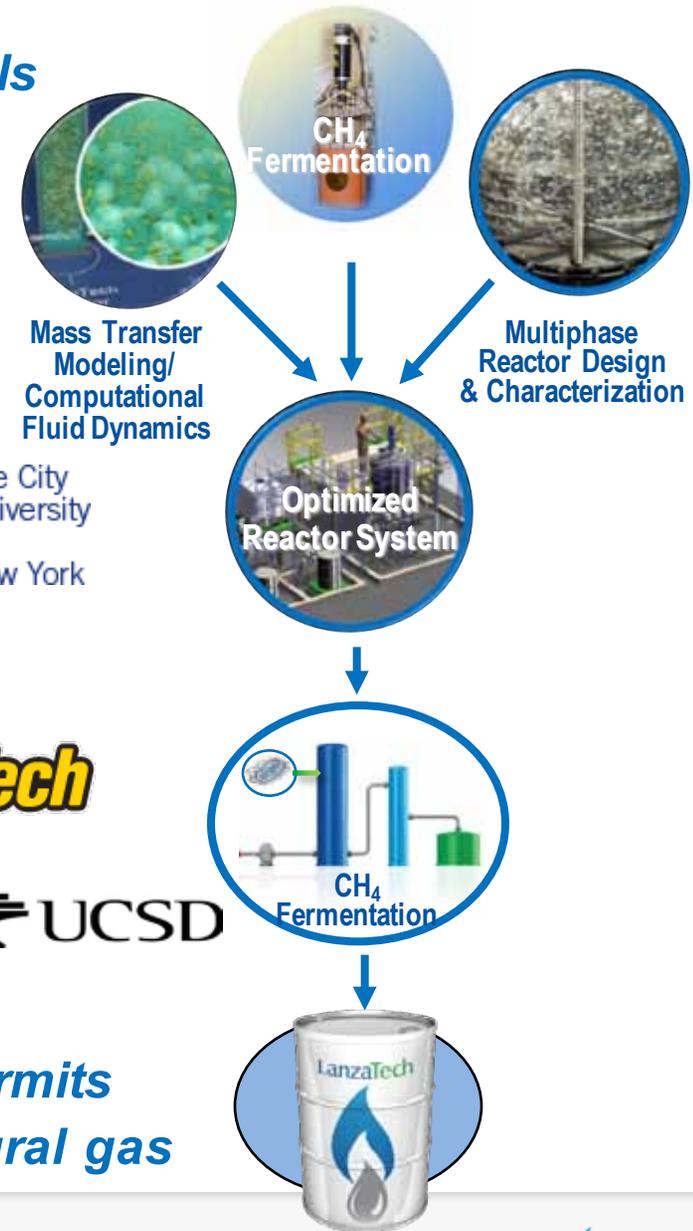


Waste natural gas to hydrocarbon fuels & chemicals

Project Enable small-scale (remote) deployment of natural gas fermentation to hydrocarbon fuels and chemicals through development of novel gas fermentation bioreactor concepts.

Project Team

- **LanzaTech** – bioreactor concept development & methane fermentation
- **City University of New York** – hydrodynamic and mass transfer experimentation
- **Louisiana State University** – computational fluid dynamic (CFD) modeling
- **Michigan Technological University** – life cycle analysis (LCA) modeling
- **University of California – San Diego & San Diego State University** – Synthetic biology for strain improvement



Efficient, small-scale methane fermentation permits capture and utilization of low quality, remote natural gas

